V.D.5 Intergovernmental Stationary Fuel Cell System Demonstration

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Subcontractors:
- Construction Engineering Research Laboratory (CERL); Champlain, IL
- Ballard Power Systems; Burnaby, British Columbia, Canada
- Keyspan (National Grid); Brooklyn, NY

Project Start Date: October 1, 2007
Project End Date: April 30, 2010

Objectives

To design and produce an advanced prototype proton exchange membrane (PEM) fuel cell system with the following features:

- 5 kW net electric output
- Flex fuel capable – liquefied petroleum gas (LPG), natural gas (NG), ethanol
- Reduce material and production cost and increase durability
- Increase electrical efficiency over the current alpha design
- Increase total efficiency by incorporating combined heat and power (CHP) capability

To show a path to meet long term DOE objectives:

- 40% system electrical efficiency
- 40,000-hour system/fuel cell stack life
- $750/kW integrated system cost (with reformer)

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4.4) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(B) Cost
(C) Performance

Technical Targets

Integrated Stationary PEM Fuel Cell Power Systems (5-250 kW) Operating on Reformate: This project is conducting fundamental analysis and demonstration of fuel flexible (ethanol/LPG) CHP integrated system. Results of the current system design have shown the ability to meet the following DOE 2011 targets.

- Survivability (min and max ambient temperature) -35 to +40°C
  - Successful system operation shown from -40°C to +46°C
- Noise < 55 dB(A) at 10 m
  - Measured noise emissions of <60 dB(A) at 3 m at rated power at nominal ambient conditions which when applying the inverse square law equals 49.5 dB(A) at 10 m

Learning gained from work activities of this project will be applied toward the design and manufacture of a system that is on a path to meet the following DOE 2011 targets:

- Durability at <10% rated power degradation: 40,000 hours
- Cost at 2,000 units/year: $750/kW$_e$
- Performance (target values adjusted to account for LPG-fueled system)
  - Electrical efficiency at rated power: 38.5%
  - CHP efficiency at rated power: 78.5%

Accomplishments

- Successfully completed an analytical model for a PEM fuel cell system that will reduce material cost by approximately 25%, increase system efficiency by 4-5% and significantly improve reliability when compared to current technology.
- Achieved system operation on ethanol-based feedstock [1].

- Developed an analytical system model using data from above to optimize system design for ethanol fuel that when commercially viable could reduce operating costs by 54% when compared to an equivalent LPG-fueled system [2,3].
- Began the work necessary to improve system and fuel cell stack durability through integration of improved technology.

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Introduction

Long term commercial acceptance of PEM-based fuel cell systems is contingent on reducing the material and operating costs and improving the durability of the system and its components. The current technologies employed for PEM fuel cell stacks and the uniqueness of other system components contribute significantly to the material cost of the system. Commonly used hydrocarbon-based fuels such as NG and LPG although technologically easier and more widely used, do not offer the environmental friendliness and potentially more cost effective means that a renewable fuel stock such as ethanol would.

This project will not only advance the state-of-the-art of PEM fuel cell technologies, but will also establish an integrated, low-cost, flex-fuel reformer for on-site fuel cell power generation. These achievements, in turn, will help to enable commercialization of the technology by improving economic feasibility and providing multiple fuel options for a variety of commercial applications. This project will include the design, manufacture, test and field demonstration of a CHP, grid-connected fuel cell system. The resulting system will advance the state-of-the-art toward the Department of Energy's program objectives of increased durability, reduced cost and improved efficiency.

Approach

To achieve these objectives Plug Power will use experience in systems engineering and integration gained from over 600 systems installed and operated worldwide to perform concept development and detail design of an ethanol/LPG flex-fuel capable fuel cell system that incorporates new technologies necessary to advance toward meeting the DOE 2011 targets for durability, cost and performance (see Figures 1-3).

Results

In the past year the main focus of this project has been on defining the product requirements and selecting the technologies necessary to form a system capable of supporting a viable business case for a commercial product. Our modular system architecture is extremely flexible and could be customized for different fuel types and end use application requirements by adding optional kits to the base design (Figure 4). Typical product requirements for a scalable commercial telecom fuel cell product can be found in Table 1.

A system model for performance and cost of ownership has be created which can be used to predict the effect new technologies would have on the total cost of ownership of the fuel cell system. This model can be used for design trade-off analysis as well as a marketing tool to show potential customers and end users the effect fuel cell technology could have on their particular

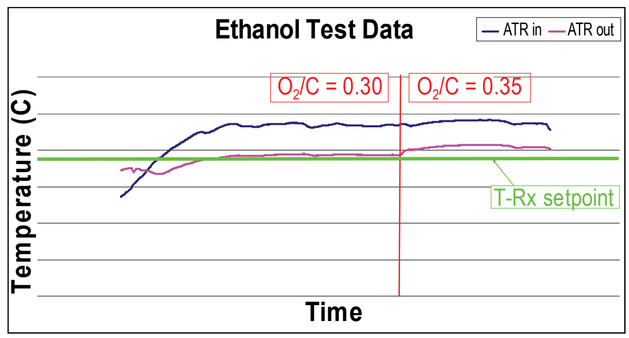

FIGURE 1. System Operation on Ethanol Fuel

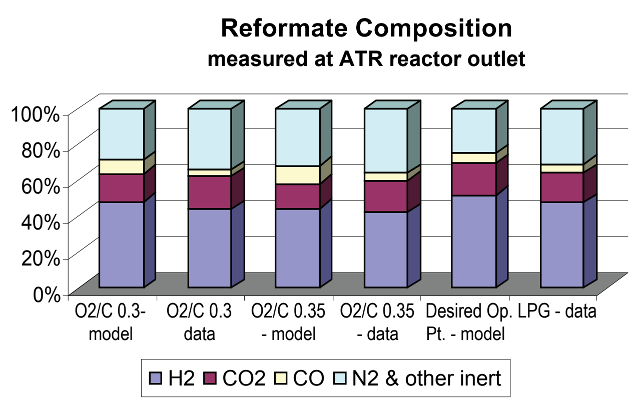

FIGURE 2. System Simulation and Test Results - Ethanol

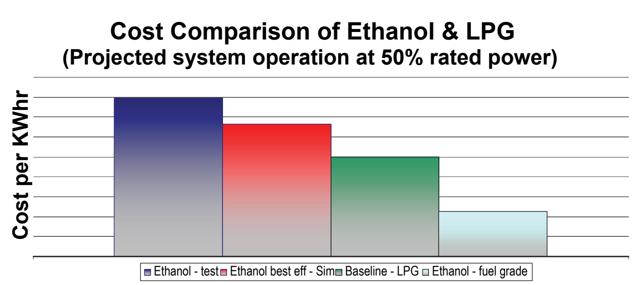

FIGURE 3. Operating Cost Comparison

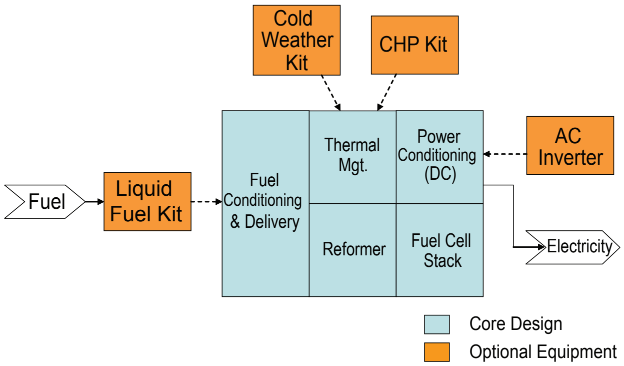

FIGURE 4. System Architecture

TABLE 1. Product Requirements

	Model	GenSys Telecom Product 3T24 / 48	6T24 / 48
Product Requirement			
Power Rating			
Max Continuous Power (Net BOL)	watts	3,000	6,000
Min Continuous Power	watts	750	1,500
EOL Continuous Power	watts	2400	4,800
Power Output			
Nominal Voltage		27.25 / 54.5	
Max voltage		30 / 60	
Min voltage		21 / 42	
Heat Output			
Heat recovery kit		No	
Peak CHP efficiency	%	N/A	
Usage Profile			
Duty cycle		Continuous	
On/off duty cycles	#/yr	10	
Operating Conditions			
Operating Ambient Temp	°C	-5 to 50	
Operating Altitude - (min / max)	m	-60 / 2000	
Water Independent Operation		No make-up water required	
Audible Noise - (Nominal / Max)	dBa	60 / 70	
Freeze Prevention Heater		Optional low temp kit	
Fuel			
Primary Fuel		LPG	
Secondary Fuel		Natural Gas	
Optional Fuel		Liquid (ex. Pure Ethanol)	

application. Once operational data from the prototype system is available this will be used to validate the model and update it with the learning gained from the demonstration.

Successful operation on laboratory-grade ethanol feedstock has been completed on prototype hardware. This hardware has been integrated onto a test system. This system was operated to gain data necessary to complete a system model to develop the work items necessary to optimize the system design to use an ethanol-based fuel.

The project has progressed technically to a point where system definition, design and development are possible that will culminate in a field ready prototype in early 2009.

Conclusions and Future Directions

As a result of activities of this past year Plug Power was able to define the steps necessary to develop a system capable of being commercially viable and show progress toward meeting DOE's 2011 goals. Successful operation on ethanol feedstock was achieved and the system modifications necessary to optimize operation on this fuel were defined. At this time the need for laboratory-grade ethanol to prevent poisoning of the reformer catalysts challenges the economics of using ethanol as a fuel. No further work on using ethanol as a fuel is planned as part of this project. If technology advances so alternative denaturants can be used or catalyst technology progresses to a point where using automotive grade ethanol is possible the work to incorporate the necessary items to optimize ethanol operation could be finished.

For the remainder of the project we have defined the following tasks necessary to bring this project to a successful conclusion.

- Remainder 2008
  - Complete prototype component testing of fuel cell stack.
  - Conclude concept development activities and exit concept design review phase gate.
  - Finalize system specifications and module flow downs.
  - Complete prototype system design.
  - Pass integrated system design review and exit Phase 1 of project.
- Fiscal Year 2009
  - Build prototype system.
  - Perform system level problem identification and design verification tests.
  - Conduct field readiness review.
  - Complete site planning and system installation.
  - Commission prototype system and commence field operation and support.
- FY 2010
  - Complete field operation and support.
  - Decommission system.
  - Post demonstration testing.
  - Project close-out.